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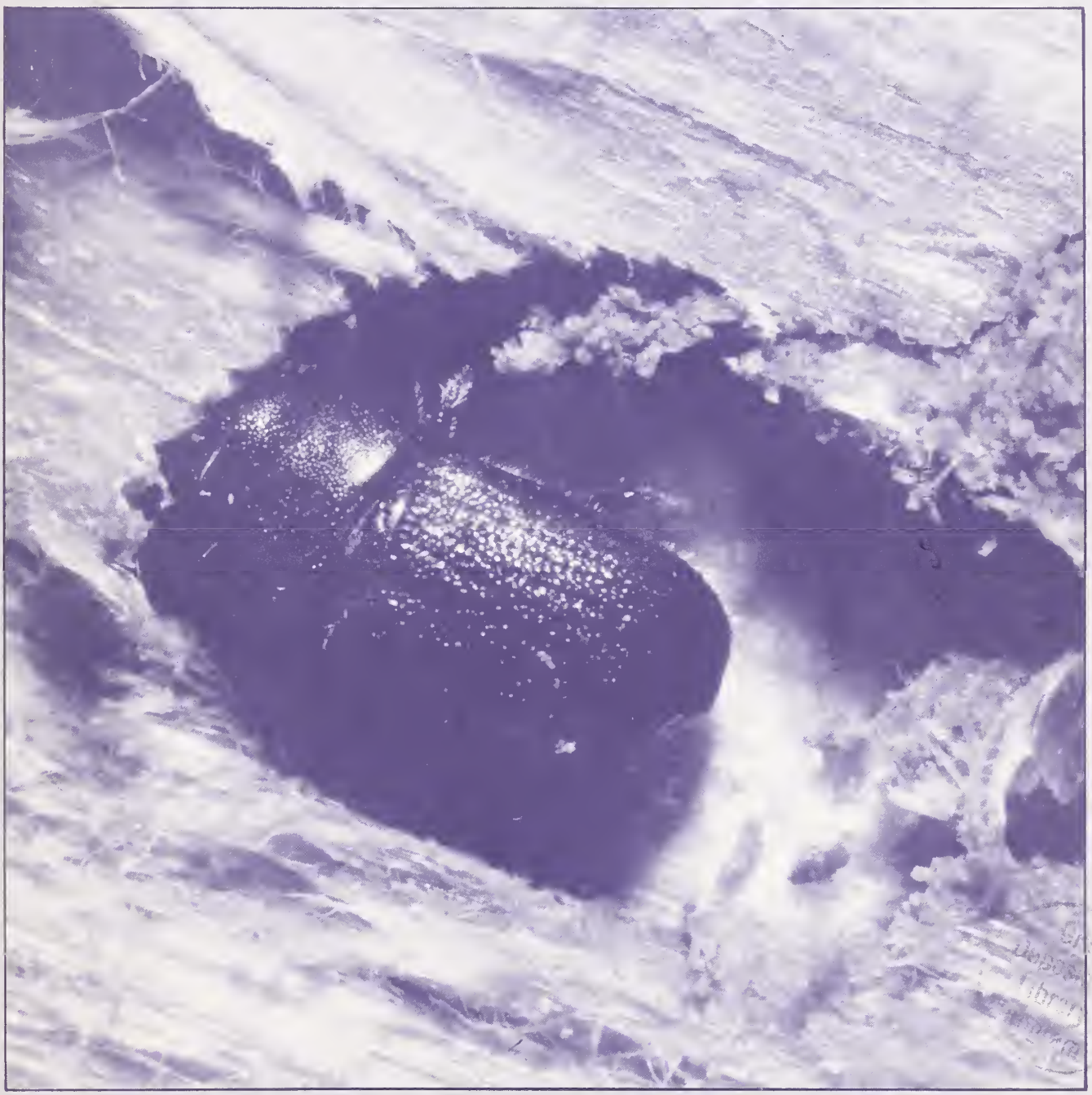

A report for land managers on recent developments in forestry research at the four western Experiment Stations of the Forest Service, U.S. Department of Agriculture.

Forestry Research West

In This Issue

Cover

A female spruce beetle deposits eggs on a white spruce. Scientists with the Pacific Northwest Station are conducting pheromone research in Alaska to develop strategies for reducing insect damage. Details begin on page12.

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P.O. Box 245
Berkeley, California 94701

Intermountain Research Station (INT)
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Ogden, Utah 84401

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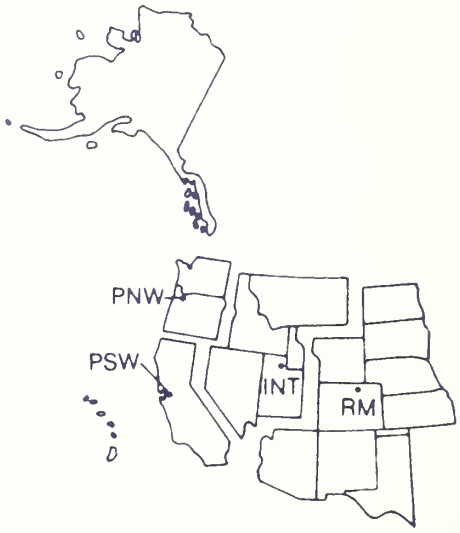


Acid test for New Perspectives

by David Tippets
Intermountain Station

At the current rate of decline, half of all quaking aspen will be gone from western landscapes within 400 years. The other half will remain in a climatic equilibrium, dominated by old trees, without a range of age classes important to wildlife. Although traditionally thought of by foresters as a weed species, no tree enhances wildlife habitat values more than aspen—the only wide-spread deciduous tree to create mosiacs of mixed forest with western evergreens.

Will "New Perspectives," an evolving Forest Service management philosophy that emphasizes biodiversity, sustainability, and ecosystem management, bring about management changes to preserve quaking aspen on western landscapes? Keeping aspen on the land may prove to be a tougher test than keeping the spotted owl in the forest. For aspen to thrive over its 7 million acres scattered across the West, fire must return to its natural historical frequency, and grazing use must be controlled until young aspen grow tall enough to survive browsing.

"Long-term "benign neglect' has made the need for a greatly expanded recycling effort critically important on many areas," Utah State University Range/wildlife Professor Phil Urness told a Society of American Foresters audience in 1985, building a case for why forests should include a diverse mosaic of plant communities. He pointed out that by eliminating the natural fire cycle that regenerates aspen, succession to less complex coniferous forests will not only reduce food for grazers and browsers, but will eliminate habitat for species that thrive in the more biologically complex mixed forest.

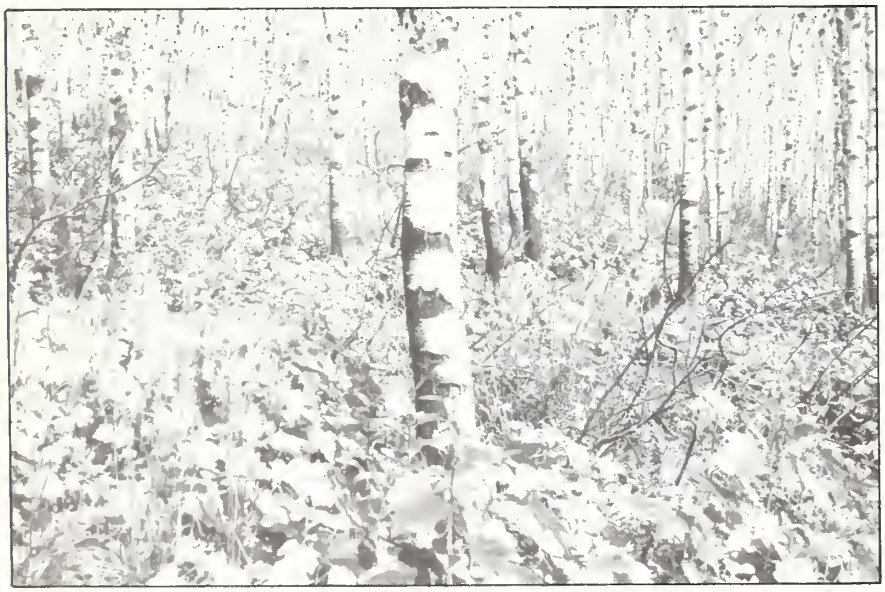
Scientists Norb DeByle (left) and Jim Brown observed the effects of different fire intensities on aspen.

Plant Ecologist Walt Mueggler sampled 713 aspen stands in Utah, Idaho, and Wyoming and determined that 95 percent were mature or overmature. Since the oldest known aspen tree is only 222 years old, its easy to picture a rapid deterioration of most aspen communities in the intermountain area.

Sick, barren, and elderly

A hundred years of fire suppression and livestock grazing created a sanctuary for sick and barren elderly aspen, rotting in the shade of taller spruce, fir, and pine. Aspen compete on the same sites suitable for conifers but maintain a competitive advantage when fire stimulates prolific suckering. In areas with a 20–40 year natural cycle for wildfire, aspen has dominated conifers for the last several thousand years. But stomp out the fires and roughly half of all aspen communities succeed to conifers.

The understory of a Manning Basin aspen stand one week after the prescribed fire, and the same view one year later.



The increased grazing pressure that accompanied white settlement compounded the problem. Aspen thrive in productive areas that have been valued for summer grazing since pioneer times. Some aspen stands with tall forb understories can produce over 4,000 pounds per acre of forage, making them some of the most productive of all western range types. Not only do cattle and sheep graze off many of the tender young aspen suckers needed to regenerate the stands, they remove much of the fine fuel, often making it impossible for wildfire to burn through the stands. In extreme cases, grazing pressure has induced changes in understory vegetation to exotics such as Kentucky bluegrass and annual forbs that don't produce enough fuel to burn the stands.

In some areas of the West, expanding elk herds have made regeneration of aspen on winter range impossible, illustrating that maintaining aspen on the landscape may require the ability to control all ungulate grazing and not just domestic livestock.

The Forest Service's first range ecologist Arthur W. Sampson recognized the dilemma soon after initiating his first research at the Great Basin Station, and by 1918 published management recommendations to promote aspen regeneration. He learned that even where aspen suckering occurred, intense domestic grazing killed the new growth and prevented regeneration. He further observed that suckers grow to a height above where livestock browse off the meristem tissue in 3-to-5 years;

he recommended protection from grazing for these periods to insure survival. Sampson's recommendations were both simple and correct, but managers have faced a complex social and political environment in which to apply the recommendations. After 72 years, the first useful aspen management research remains largely unapplied as aspen continues to decline.

The Intermountain Research Station, heir to Sampson's Great Basin research, continued the quest for answers to aspen problems through the Aspen and Fire Effects Research Work Units in Logan and Missoula. "The ground has been thoroughly p1owed," Urness said, referring to aspen research.

By reviewing the literature that sprouted from that thoroughly plowed ground, one can see why preserving aspen forests may become New Perspectives acid test. Burning the decadent stands to regenerate them ranges from difficult to impossible under typical constraints for prescribed fire.

Recognize opportunity

The key is recognizing good opportunities," Fire Effects Project Leader Jim Brown said recently, explaining that his project's research has provided managers with information about which community types are the best candidates for treatment.

If managers don't carefully select stands based on probability of success, burning conditions are even more critical. Without good stand data and good planning, hitting the window of opportunity resembles shooting a small running target with a rifle. And then getting a chance to shoot only after having to wait for years for the window to open for just a couple of days.

"Its the managers dilemma," past aspen researcher Norb DeByle said, during a recent interview. "The window may not open for a decade."

"Careful planning and diligent preparation are critical," Brown said. "The Prescription isn't as forgiving as it is in sagebrush . . . you have to be ready at a day's notice."

Aspen researcher Norb DeByle illustrated the height and rapid growth of aspen suckers after the old trees are killed by fire.

Brown suggests that where only small areas of aspen are included with sagebrush or conifer encroachment burns, that managers write prescriptions for the aspen rather than the sagebrush or conifers. If you target the aspen you will have a high probability of success in the other communities, but not the other way around.

Getting the right weather and fuel conditions to burn is tough enough. But add grazing policies that limit managers to occasional rest years or periods of non use, and the odds of maintaining aspen with fire look worse than a crap shoot. Sampson's research showed that to maximize sucker survival, managers should rest burned areas on sheep allotments for three years, and five years on cattle allotments—advice that that's pretty tough to follow on active grazing allotments.

Prioritize diversity over production

But New Perspectives allows a broader definition of success based on sustaining all biological productivity with a greater emphasis on landscape management and biodiversity, rather than the traditional forestry philosophy that emphasized maximizing fiber production. Brown explains that maximizing suckering may not be needed to prevent succession to conifers and maintaining an aspen mosaic on the landscape. He explains that if you know and understand aspen habitat types and livestock behavior you can identify some stands that can be burned and regenerated without resting from livestock grazing.

Scientists used tame elk to study elk diet preferences after fire.

"You can tolerate light grazing," Brown said, adding that communities with a light conifer overstory are unlikely to be heavily grazed before or immediately after burning. One year rest and one year deferment might be adequate for many stands. Suckers will respond to grazing by producing lateral shoots and can survive as long as they aren't cropped off "year after year."

"You have to evaluate preburn grazing in the community," Brown insists, indicating another strata of resource inventory data that is important to vegetation management. To successfully manage aspen on the landscape, a resource inventory needs to include as much data on non-commercial aspen stands as has traditionally been collected only for commercial stands. Aspen-ecosystem-landscape management demands an integrated resource inventory with compatible strata of timber, fuels, wildlife, and range.

Clearcutting or mechanical treatments can be substituted for fire, often providing more effective and economical alternatives. But these methods alone can't address all concerns for ecologically based landscape management. The ecological influences of natural fire are too fundamental for managers to overlook. The role of fire in ecosystem health extends far beyond aspen regeneration alone.

"Fire treats the entire vegetative community and not just the trees," Brown emphasized. "Biodiversity is made up of a diverse landscape and a large number of species," he said, explaining that the historical role of fire seems woven through the heart of New Perspectives concerns. Historically, the same natural fire that maintained aspen on the landscape, also created the mosaic of other kinds and ages of vegetation essential to the survival of many species.

From Sampson's first research, through the work of DeByle, Mueggler, and others, to the current work of Brown's Fire Effects research unit, Intermountain Station scientists have given managers the basic knowledge they need to preserve aspen. More research will help reduce the risks of prescribed fire and make aspen management easier. Application of research information will help change the odds in the manager's favor. But the greatest limitations are neither climatic, biological, or lack of scientific knowledge.

The biggest problem

"The biggest problem is logistics and manpower . . . the way we plan, budget, and set targets," Brown said, explaining why aspen continues to decline in the face of knowledge of how to reverse the trend. Even seemingly little things like the changing of the fiscal year during the peak burning season for aspen can have a dramatic effect on whether or not burning prescriptions are implemented. If New Perspectives' commitment and enthusiasm can clear the path of internal stumbling blocks, the scientific foundation is already laid for aspen management.

Jim Brown monitoring the highly successful Manning Basin prescribed fire on the Caribou National Forest in Idaho.

Appraising Fuels and Flammability in Western Aspen: A Prescribed Fire Guide, by Brown and Dennis G. Simmerman, is the best information available for fire managers who want to write quality prescriptions to successfully regenerate aspen. Brown and Simmerman paint a good picture of the "small moving target of burning" window, telling managers when and where they can burn to expect success within acceptable limits of risk. The publication, General Technical Report INT-205, should be on the bookshelf of every land manager and resource specialist charged with maintaining landscape and biodiversity in the interior west.

Brown and Simmerman show color photographs of different aspen community types with different fuel loadings, and rate the probability of a successful prescribed fire. At first glance numerous charts and graphs make the report appear like a typical research publication, but closer inspection reveals that these fire scientists have done an exceptional job of simplifying research results to make the information easy for managers to understand and apply.

Aspen's acid test for New Perspectives will be to apply research information and preserve aspen within the political, social, and economic environments that constrain prescribed fire and limit the control of both wild ungulate and domestic livestock grazing.

Small clearcuts help regeneration

by Rick Fletcher
Rocky Mountain Station

Southwestern mixed conifer forests are found on high-elevation sites, generally above 8,000 feet, throughout Arizona, New Mexico, and southwestern Colorado. These forests are important sources of commercial and noncommercial resources. Natural regeneration is satisfactory in most undisturbed stands. These contain adequate density and stocking of advance regeneration to replace trees lost by natural mortality or by moderate harvesting. However, natural regeneration has been poor in large openings that were created by harvesting or by natural disturbances, partially because seedfall cannot reach sites in the interior of such openings.

Scientists at the Rocky Mountain Station's Forestry Sciences Lab in Flagstaff, Arizona have been experimenting with small clearcut openings of about one to two acres in an effort to increase natural regeneration. "For some time, the creation of such patch clearcuts have been advocated as a method of increasing water yields, as well as enhancing other resource values," says Research Forester Gerald Gottfried. "We're finding that such a prescription can also sustain forest productivity." Under this prescription, a portion of the watershed is patch clearcut periodically throughout the rotation. Once harvested, the openings regenerate naturally, and eventually contain sufficient timber to be harvested again at the end of a 120-year rotation. In addition to the greater availability of seed from the surrounding stand, small openings have a more moderate microclimate, as well as better moisture conditions than larger openings.

New regeneration in a small clearcut.

Beginnings

In 1978, the Rocky Mountain Forest and Range Experiment Station and the Apache-Sitgreaves National Forests designed a silvicultural prescription that included creating small dispersed openings by patch clearcutting and group selection methods, in conjunction with single-tree selection in the adjacent stand. A resource allocation evaluation indicated that this prescription would benefit the greatest mix of resources, such as water yields, herbage production, wildlife habitat, and tree and stand growth. Peter Ffolliott, a cooperator from the University of Arizona's School of Renewable Natural Resources at Tucson, and Gottfried designed an experiment to evaluate the amount, composition, and stocking of natural mixed conifer and aspen regeneration in small clearcuts and to compare it to regeneration in the surrounding partially harvested forest.

TABLE 1

Opening number	Area (acres)	Basal area (ft^2/acre) $\bar{X} \pm SE$	Mean tree height (ft) $\bar{X} \pm SE$	Most common species (percent by basal area per acre)
1	1.2	146 ± 29	64 ± 7	White fir (26%), ponderosa pine (23%)
2	0.8	156 ± 20	94 ± 6	Douglas-fir (40%), white fir (15%)
3	1.1	148 ± 22	90 ± 5	Douglas-fir (44%), white fir (13%)
4	1.1	158 ± 22	59 ± 6	Douglas-fir (54%), ponderosa pine (22%)
5	0.8	158 ± 21	62 ± 7	Douglas-fir (59%), aspen (21%)
6	0.3	169 ± 26	72 ± 7	Douglas-fir (51%), Engelmann spruce (12%)
7	1.1	123 ± 23	57 ± 4	Engelmann spruce (32%), Douglas-fir (27%)
8	1.0	208 ± 31	56 ± 5	Aspen (34%), Douglas-fir (26%)
9	1.6	191 ± 22	85 ± 6	Douglas-fir (45%), white fir (45%)
Total study area	1.0 ± 0.1	162 ± 8	71 ± 5	

Characteristics of the nine clearings and adjacent partially harvested stands.

The research was conducted on the South Fork of Thomas Creek, a 562-acre watershed within the Apache-Sitgreaves National Forests of east central Arizona. The watershed originally supported an old-growth, uneven-aged mixed conifer forest consisting of eight main tree species: Engelmann spruce, blue spruce, Douglas-fir, white fir, corkbark fir, ponderosa pine, southwestern white pine, and aspen. Douglas-fir is the most common species, while ponderosa pine is the most commercially valuable. The stand consisted of a mosaic of groups and patches of various sizes and species compositions. Much of the watershed has been classified as belonging to the *Picea engelmannii/Senecio cardamine* habitat type, although other habitat types occur locally within the area.

The plan

The multiresource prescription was prepared for 422 acres in the upper part of the South Fork watershed. The prescription called for group selection and single-tree selection on 233 acres, patch clearcutting and single-tree selection on 159 acres, and single-tree selection on 28 acres adjacent to the stream channel. Two acres of meadow were left undisturbed. The harvest removed 34 percent of the stand basal area and created 63 dispersed openings throughout the stand.

Prior to treatment in 1978, established mixed conifer seedlings and aspen suckers were measured in nine forested areas marked for patch clearcutting. These data provided an indication of pretreatment conditions on the study area. Following the harvest, nine of the harvested clearings were selected for intensive study. The characteristics of the nine sites and surrounding stands are shown in table 1. Regeneration was monitored on permanent transects and plots within each opening and surrounding stand. Seedling measurements, including number of stems, species, and percent stocking, were made in 1982, 1983, 1986, and 1989, representing 4, 5, 8, and 11 years following treatment.

The preharvest inventory measured approximately 1,746 seedlings and suckers per acre less than one foot in height (table 2). Douglas-fir and white fir accounted for 67 percent of the trees and aspen accounted for 25 percent. "In 1982, the first year of postharvesting sampling, all of the nine openings and all of the partially harvested areas were satisfactorily regenerated, containing at least 325 seedlings or suckers per acre, the level considered to indicate satisfactory density for similar mixed conifer stands. In fact, the openings averaged 2,605 stems per acre and the forested areas averaged 4,184 stems per acre," says Gottfried. Douglas-fir and white fir seedlings were the most common species in the openings and in the forest.

In 1983, regeneration densities fell sharply in both forested and open sites; differences between 1982 and 1983 were highly significant. The 1983 inventory indicated that only six of the openings contained satisfactory numbers of seedlings and suckers. One opening which had over 1,000 stems per acre in 1982, contained no regeneration in 1983. All forested sites contained at least 325 stems per acre. The average clearing contained 1,082 trees per acre, while the average forested area contained 2,272 trees per acre. General conifer and aspen numbers were similar between the two cover types.

1986 data

By 1986, seedling densities appeared to be recovering, but the new levels still were below those of 1982; they were similar to 1983. Eight of the openings and all of the forested sites contained satisfactory numbers of seedlings and suckers. "However," Ffolliott says, "the difference between the two cover conditions had become significant." In 1986, Douglas-fir and white fir were between 50 percent and 60 percent of the regeneration in both conditions, while aspen made up 26 percent of the trees in the openings and 11 percent of those in the forest.

Total regeneration density remained constant between 1986 and 1989 and continued to be below 1982 levels. The openings contained 1,014 trees per acre and the forested areas contained 3,092 trees per acre. The difference between density in the openings and in the forest was still significant. Eight openings and all forested areas contained satisfactory seedling and sucker densities. Differences were found between overall population of conifers; however, white fir was the only species to show a difference. Douglas-fir and white fir accounted for 53 percent of the regeneration in the forest and 47 percent of that in the clearings. The proportion of spruce increased from 11 percent to 32 percent in the forest and from 9 percent to 24 percent in the clearings between 1982 and 1989.

The pretreatment inventory indicated that about 88 percent of the plots were stocked with at least one healthy seedling or aspen sucker. Stocking evaluations following treatment showed no statistical differences between forested and open areas over the study period. Stocking dropped significantly between 1982 and 1983 and remained constant afterwards. Gottfried indicates that stocking, in 1989, ranged from 0 to 100 percent in the clearcut openings, with an average of 45 percent, and ranged from 20 percent to 92 percent in the forest, with an average of 61 percent. Most of the trees in the clearings were adjacent to the treeline; only two areas had trees in the center.

11 years later

"This study showed that by 1989, 11 years after the timber harvest, eight of the nine monitored clearings had regenerated satisfactorily, with an average density of over 1,000 new seedlings and suckers per acre," states Gottfried. Although this was less than the density under the adjacent partially harvested forest, it was sufficient to regenerate the openings. Each of the eight stocked openings contained at least 325 trees per acre. Regeneration densities under the forest, which had been harvested according to the single-tree selection method, were also greater than that considered satisfactory and greater than that

measured before treatment. The stocking results for the clearings were less satisfactory; however, the center areas of the clearings should become stocked in the future as surrounding established seedlings grow and further modify the microclimate in the openings.

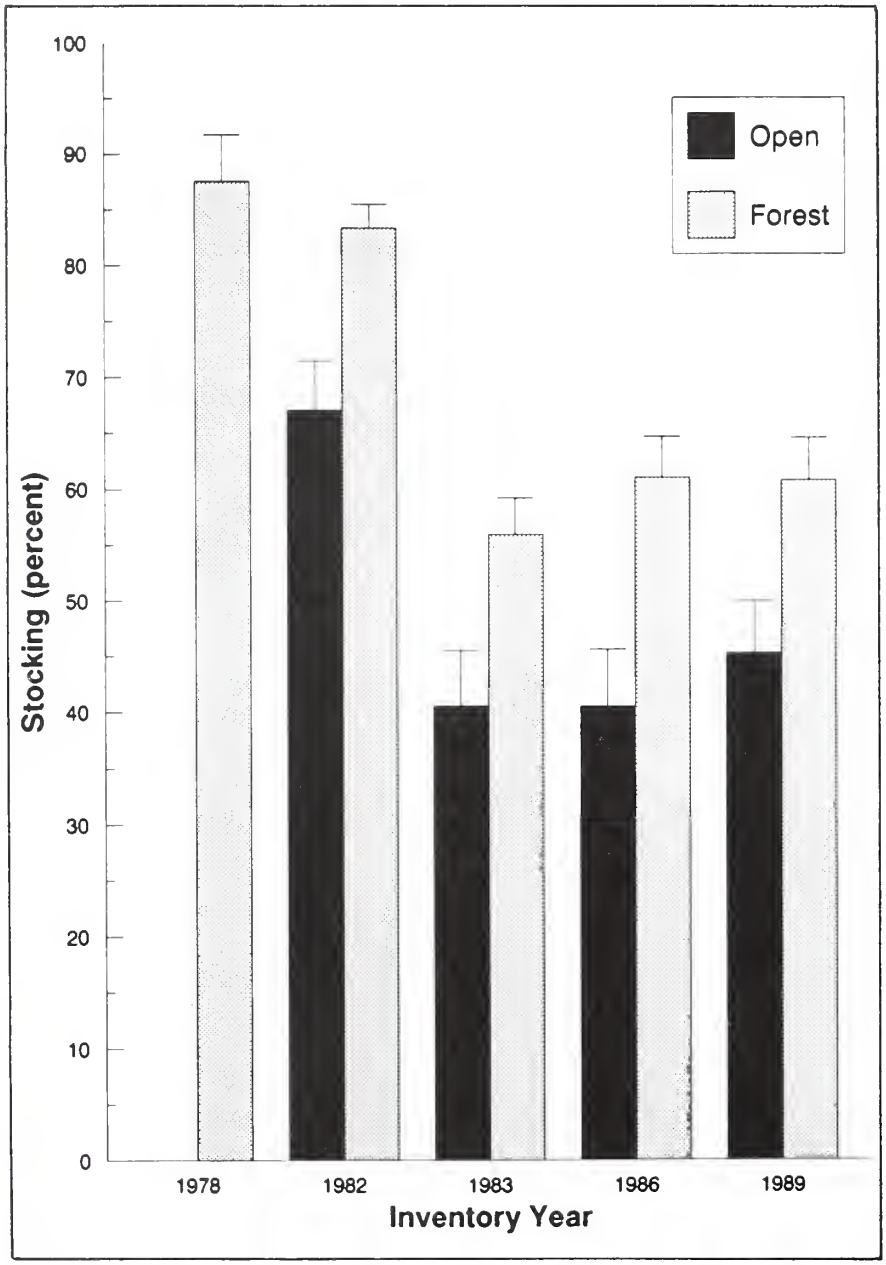
Although each of the species has its own requirements for germination and establishment, the conifer species generally have followed the same pattern of fluctuations as found for the total regeneration densities. Individual species population densities have remained similar within the partially harvested stand and the openings throughout the study. Only white fir numbers were different for the two cover categories for each of the surveys. Gottfried explains that true firs and spruce can be at more of a disadvantage during drought than pines because of their shallow and slow-growing root systems. "More drought-hardy species have rapid-growing root systems, which can tap moisture from deeper soil layers where evaporation losses are less. Young seedlings in the clearings are sub-

TABLE 2

Species	1978	1982	1983	1986	1989
Douglas-fir					
Forest	611 ± 51	919 ± 297	324 ± 116	712 ± 270	376 ± 126
Open		998 ± 592	189 ± 116	440 ± 169	335 ± 155
White fir					
Forest	555 ± 88	2234 ± 517	1239 ± 303	1015 ± 245	1275 ± 348
Open		1081 ± 823	273 ± 111	118 ± 57	141 ± 65
Engelmann spruce					
Forest	44 ± 28	448 ± 151	296 ± 203	932 ± 389	974 ± 322
Open		224 ± 76	54 ± 28	133 ± 64	247 ± 173
Ponderosa pine					
Forest	32 ± 20	18 ± 12	69 ± 33	28 ± 20	28 ± 14
Open		57 ± 29	63 ± 46	126 ± 63	144 ± 73
Southwestern white pine					
Forest	68 ± 31	63 ± 18	18 ± 12	0	56 ± 20
Open		41 ± 28	0	0	47 ± 31
Total conifers					
Forest	1311 ± 102	3682 ± 716	1947 ± 414	2687 ± 698	2709 ± 559
Open		2400 ± 916	579 ± 158	817 ± 226	913 ± 280
Aspen					
Forest	435 ± 86	502 ± 153	324 ± 89	321 ± 100	384 ± 135
Open		205 ± 164	503 ± 382	281 ± 97	100 ± 69
TOTAL STUDY AREA					
Forest	1746 ± 123	4184 ± 817	2272 ± 453	3008 ± 701	3092 ± 623
Open		2605 ± 902	1082 ± 466	1098 ± 298	1014 ± 266

[1]*Columns may not add up exactly because of rounding to integer values.*

Total, conifer, and individual species regeneration density per acre



Average percent stocking was similar for both the openings (O) and forested areas (F) over the study.

ject to greater environmental stresses than seedlings protected by the forest canopy." he says. Solar radiation and temperature are higher in the openings during the day, although small openings have more moderate microclimates than larger clearings. Greater herbaceous cover in the openings could also impact tree germination and survival.

Ideally, clearings can be created that will favor one species or group of species over other alternatives. It was expected, for example, that openings might provide sufficient light to encourage regeneration of shade-intolerant ponderosa pine. Although, the four inventories did not show any differences between densities in the forest and the openings for this pine, the relative importance of ponderosa pine within openings did appear to show an increase over time. Ffolliott indicates that aspen, another shade-intolerant species, should also have benefited from the clearings but that this species only made up 10 percent of the final total density. It is possible that the openings were too small to allow sufficient light to penetrate to the soil surface to stimulate abundant suckering. Poor aspen response could also be related to apical dominance of adjacent larger aspen trees which can suppress suckering activity, as well as to increased utilization of the openings by wildlife and livestock. Larger openings should be more beneficial for these species,

but the best size has not been determined. The success of spruce in the clearings may indicate that the size, shape, or orientation of the openings was beneficial for this species.

"Overall, regeneration was better in the small clearings than in the large clearcuts or in an adjacent heavily harvested diameter-limit area," says Gottfried. "Better reproduction resulted for a number of reasons. Small openings generally receive sufficient seed because most of the regeneration sites are within 198 feet of the forest edge. Small openings have more moderate microclimates than larger openings—there is more shade in small clearings from the surrounding overstory, which tends to reduce soil and air temperatures; and there is less wind movement, which impacts air mixing and the pressure gradients that affect evapotranspiration." Ffolliott points out that small openings also enhance snow accumulations—greater snowpacks, remaining on the site longer, should result in more soil moisture for tree growth and survival.

The implications from Ffolliott's and Gottfried's study are clear: patch clearcutting or group selection openings of similar sizes will result in satisfactory regeneration of forest tree species. The species mixes produced by the silvicultural methods appear consistent with those expected for the habitat type. Clearcutting should favor aspen and Douglas-fir. Douglas-fir was favored at Thomas Creek but aspen was less successful. Larger openings may stimulate more aspen regeneration but small openings appear to be less beneficial. This must be considered if aspen regeneration for wildlife is a prime objective. "A knowledge of the relationship between species and optimum clearing size for successful regeneration can give managers more flexibility to manipulate stands to obtain the species composition specified in the forest plans," says Gottfried.

The Thomas Creek Prescription is compatible with the integrated resource management philosophy, which recognizes that all natural resources are interrelated and that an interdisciplinary approach is necessary when designing projects. Satisfactory regeneration and increased growth of residual trees, coupled with the benefits of increased water yields and herbaceous production for wildlife and livestock indicate the value of the experimental treatment at Thomas Creek. The findings also should be valid for similar old-growth stands, as well as for stands that have been lightly harvested in the past. "The bottom line to all of this," explains Gottfried, "is that this type of prescription should be a valid consideration for multiresource management within the mixed conifer forests of the Southwest." If you would like additional information on this and related studies, contact Gerald Gottfried at the Forestry Sciences Laboratory, 700 South Knoles Drive, Flagstaff, AZ 86001, (602) 527–7315, FTS-765-7315.

In addition, a new report describing research at Thomas creek is available from the Rocky Mountain Station. Request *Mixed Conifer and Aspen Regeneration in Small Clearcuts Within a Partially Harvested Arizona Mixed Conifer Forest*, Research Paper RM-294.

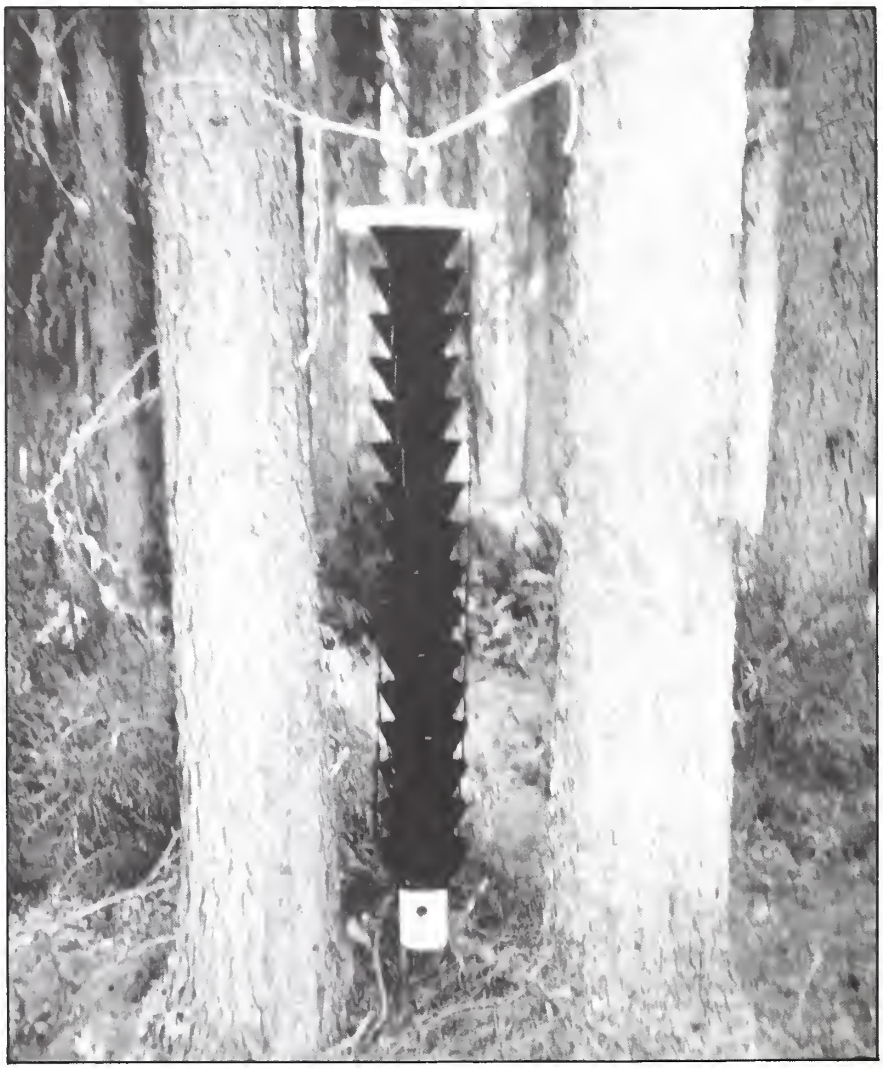
Spruce beetle pheromone research in Alaska

by Sherri Richardson
Pacific Northwest Station

As a boy growing up on a farm in a small Pennsylvania town, Richard "Skeeter" Werner would closely observe the habits of bees and hornets—he was fascinated by insect behavior. Today, Werner, a 30-year veteran in the field of entomology, is Supervisory Research Entomologist at the Pacific Northwest Research Station's Institute of Northern Forestry in Fairbanks, Alaska. He is also lead scientist for a pheromone research project in cooperation with Region 10 Forest Pest Management entomologists. The research is targeted to develop strategies to manipulate populations of spruce beetles in order to reduce damage inflicted on thousands of spruce trees each year in south-central and interior Alaska.

"The death of individual trees and entire stands represents large annual losses in forest productivity, recreation and esthetic values, and wildlife habitat," Werner says. "Another danger is that beetle-killed timber increases fuel loads within stands which, in turn, increases the risk of a catastrophic wildfire."

Pheromones are chemical substances secreted by insects that influence the behavior of members of the same species. Pheromones are located in the digestive track of bark beetles. They are released in frass which is the woody boring material the beetle produces while eating. Synthetic bark beetle pheromone has an odor like turpentine.



Lindgren funnel trap used to trap bark beetles. The trap is baited with spruce beetle.

"Pheromones are used by insects as a sexual attractant for reproduction, but they can also signify aggregation (gathering together) nor feeding," Werner explains.

"Our research seeks ways to use pheromones to manipulate the behavior of the beetles, thereby saving the trees. We are trying to find alternatives to insecticides. And, so far, pheromones seem to be the way to go."

The spruce bark beetle is a major killer of spruce. The beetle attacks trees across Canada and from the southern Rocky Mountains to Alaska. During the last 15 years, more than 1 million acres of spruce in Alaska were infested. Since 1974, beetle populations have expanded throughout south-central Alaska from the Kenai Peninsula including the Chugach National Forest and Kenai National Wildlife Refuge. The beetles have also found their way to the west side of Cook Inlet in the Beluga-Tyonek area and north to Judd Lake.

"Much of the loss has occurred in areas with high-value trees such as campgrounds, recreational areas, hiking trail systems, and urban areas of small communities," Werner says.

Collaborating with Werner on the research are Edward Holsten, an Entomologist for Region 10 Forest Pest Management, State & Private Forestry; and Patrick Shea, Research Entomologist for the Pacific Southwest Forest and Range Experiment Station in Berkeley, California.

The problem

"Endemic levels of spruce beetles can be found in almost any spruce stand in Alaska," Werner says. "The general progression for development of an outbreak would start with the attack of a few 'focus' trees."

Stressed, slow-growing trees are most likely to fall prey to the beetle attack. According to Werner, these trees then act as sites for population increases that allow the beetles to reach epidemic levels. A new brood of adult beetles emerges from the focus trees and attack the adjacent slower growing, less vigorous trees.

Stressed trees are the most prevalent host for the spruce beetle. What factors contribute to stressed conditions?

- Lack of silviculture management in over-stocked stands of slow-growing, mature, spruce trees.
- Stress on residual stands in the fringe areas of wildfire areas partially burned or damaged by smoke.
- Periodic flooding and deposition of silt on the forest floor.
- Poor utilization of felled trees and accumulation of slash following logging, rights-of-way construction, and windthrown trees.

Three components of the research

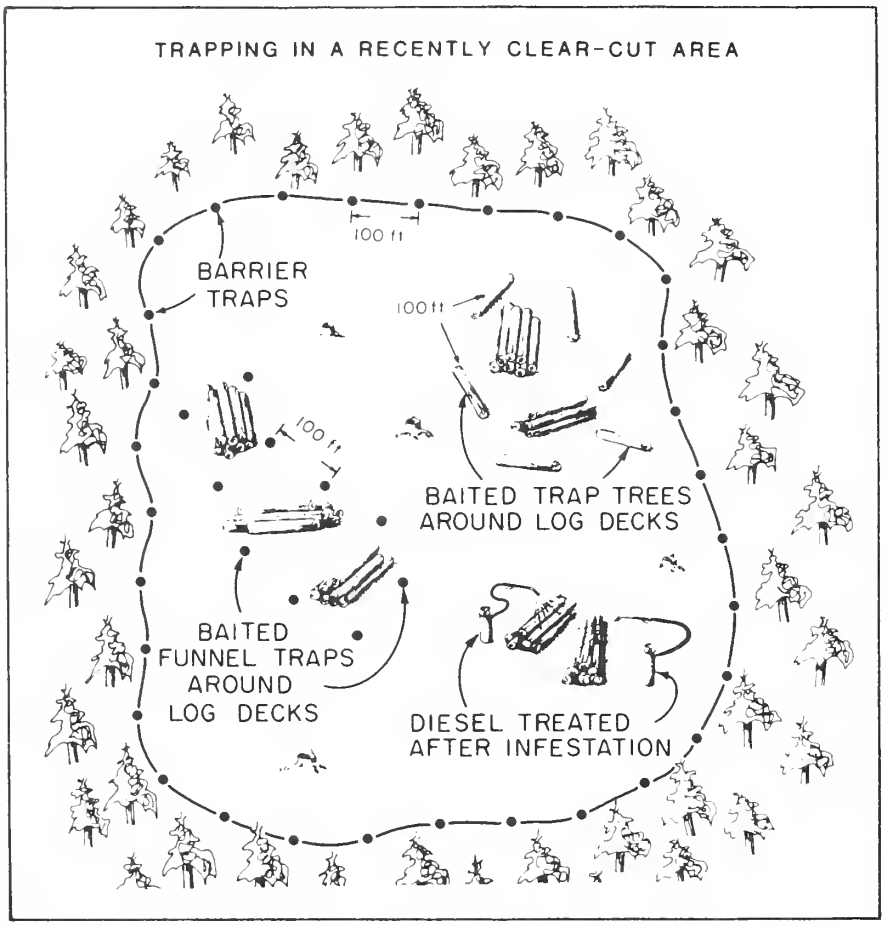
Werner's pheromone research has three major goals:

- Determine the role of bark beetle pheromones (from a variety of species) in providing competition for the spruce beetle in spruce trees in Alaska.
- Determine the effectiveness of ground and aerial application of methycyclohexenol or MCH (a spruce beetle antiaggregation pheromone).
- To develop a 5-year plan to study field testing of spruce beetle aggregation pheromone, and to produce applied technology for using pheromones.

Use of bark beetle pheromones

"Past outbreaks in south-central Alaska have been associated with warm, dry summers and an accumulation of spruce debris from windthrown and felled trees that are highly productive breeding sites for spruce beetles," Werner explains. "When beetle populations increase and a sufficient supply of breeding material is no longer available for colonization, beetles can infest nearby living trees, particularly in mature stands."

Stand manipulation or the use of chemical insecticides has been the standard way to control beetle infestation. Werner and his colleagues have been examining alternatives to insecticides. Other classic techniques for treatment of logging slash, felled, or windthrown green trees is the immediate salvage of the trees. These trees are also disposed of by burning, chipping, or burying them. The use of Environmental Protection Agency (EPA) approved insecticides or pheromone-baited traps has also been successful in areas with high value stands.



Use of baited trap trees and funnel traps to trap out spruce beetles in a recent clear cut.

An innovative technique used to combat the beetle infestations are the use of semiochemicals. Semiochemicals are used to manipulate bark beetle populations and include synthetic host-produced chemicals and pheromones that prevent attack or reduce the attack density of bark beetles to a level below the threshold density required for the development of brood trees.

Werner says this technique has several advantages. "First, the use of insecticides would be minimal. Secondly, beetle resistance to treatment would be negligible since several different pheromones from competing species of bark beetles can usually be used," he says. "And finally, there would be little direct mortality to parasites and predators as occurs with insecticide treatment."

"Field studies conducted in south-central and interior Alaska during the last 10 years were designed to determine the attractiveness of several scolytid (family name of all bark beetles) pheromones and host terpenes (chemicals in trees that attract bark beetles) to the spruce bark beetle," Werner says.

Werner and his colleagues discovered that seudenol + alpha pinene (host terpenes) dispersed from funnel or sticky traps attracted more beetles than frontalin + alpha pinene. But frontalin, when applied directly on uninfested white and Lutz spruce trees, attracted more beetles than the seudenol-alpha pinene combination.

"Host suitability is also a major factor in attracting spruce beetles to host material," Werner adds. "When white spruce is infested with spruce beetle brood, more spruce beetles are produced than when Lutz or Sitka spruce are infested. In spite of host suitability differences, spruce beetle outbreaks have been more frequent and severe in Lutz spruce."

Application of MCH

The use of MCH is being studied to reduce tree mortality by spruce beetles in scuth-central Alaska. MCH is naturally derived from female spruce beetles and is the primary antiaggregation pheromone used by the insect (Rudinsy 1973). Several studies have been performed using MCH and a pilot test using ground and aerial applications from a helicopter were done in 1991.

MCH was identified in 1974 as a major component of the spruce beetle pheromone. "Field tests have shown that granular formulation of MCH reduced attacks of spruce beetle on Engelmann spruce by 93 percent when trees were baited with MCH in Idaho," Werner says. "The addition of MCH to sticky traps baited with the natural attractant as well as synthetic pheromones suppressed attacks by spruce beetles in Lutz spruce on the Kenai National Wildlife Refuge by 87 and 99 percent respectively,"

A 5-year study plan

"We've had a real problem with spruce beetle infestations in south-central Alaska since 1974," Werner explains. "More that 1 million acres were infested. In 1986, outbreak level populations were found along the Yukon and Kuskokwim Rivers in interior Alaska where 160,000 acres had been infested. It was conceivable that the entire commercial spruce stands in the Yukon, Kuskokwim, and Tanana River Valleys could be killed."

The Yukon River Spruce Beetle Management Council was recently formed to work out strategies and solutions to this problem. The interagency council is developing and coordinating a program to evaluate the present and future impact of the spruce beetle on the environment of the residents and ecosystems of the lower Yukon River. A primary objective of the council is the development and application of preventive and suppression methodologies.

The 5-year project is a cooperative effort among FPM, Region 10, and the Institute of Northern Forestry in Fairbanks, Pacific Northwest Research Station.

"The primary purpose of the special project is to develop operational strategies for monitoring and manipulating spruce beetle populations," Werner says. "This will be accomplished by using semiochemicals in traps and on baited trees in interior and south-central Alaska."

The project is part of a larger international project involving the Forestry Institute, Forest Pest Management (Region 10), Forestry Canada, the University of Calgary, Simon Fraser University, and Phero Tech Corporation (an insect pheromone manufacturer).

Divided into two phases, the project addresses the development of new semiochemicals and the operational use of semiochemicals.

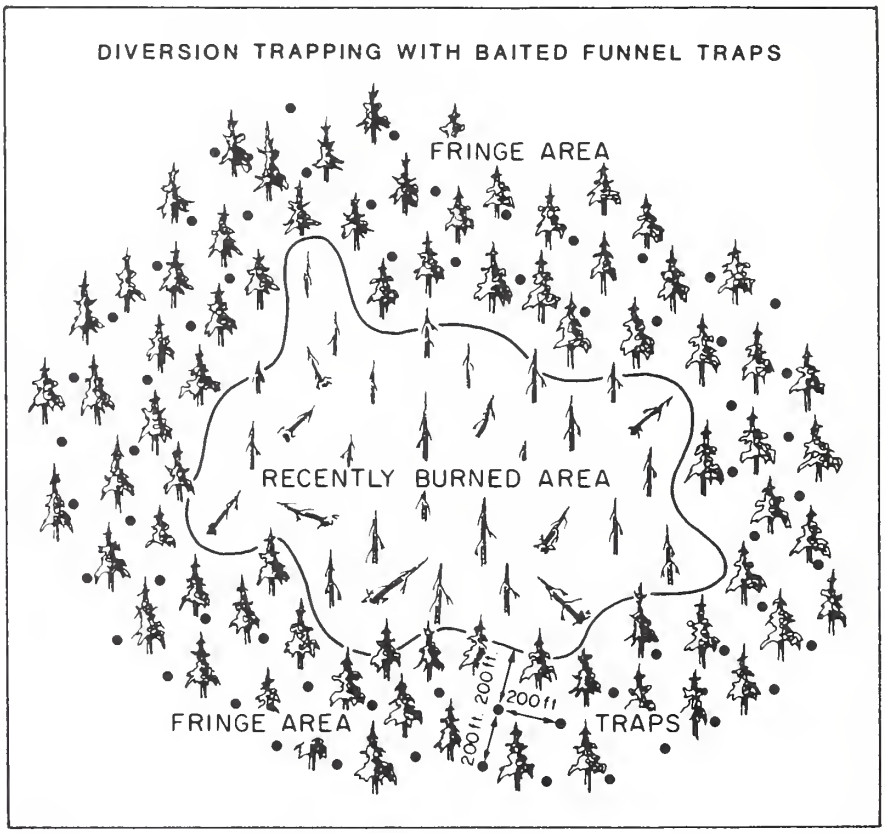
"Phase one occurred in 1988–1990 and dealt with the development of an improved pheromone blend for attracting spruce beetles. This phase included field tests on the effectiveness of the new formulations," Werner says. "The tests were conducted in northern and southern Alberta, British Columbia, and south-central and interior Alaska. Phase two will be in operation from 1991–93 and will demonstrate the efficiency of pheromone methods with improved formulations for manipulating spruce beetle populations in various management strategies."

The results of the first phase of the project resulted in several successes. Efficacy field trials were done on a new formulation of spruce beetle lure in stands of white

spruce at Bonanza Creek Experimental Forest in interior Alaska from 1988–89. "The lure was a ternary formulation which contained alpha pine, frontalin, and methylcyclohexenol (MCOL) compared to the current commercial lure produced by Phero Tech, which contains alpha pinene and frontalin," Werner explains. "The efficiency of this new lure was tested simultaneously against that of the commercial spruce beetle lure and proved superior by a wide margin. It attracted spruce beetles in much greater numbers in all areas of the field test."

Werner added that the new lure worked extremely well in Alaska in areas with endemic and epidemic beetle populations. "Trap captures as high as 1,500 per trap in 1 week were observed during peak flight in interior Alaska. The catches are attributed to the strong synergism for the components of the ternary bait," he adds. Final tests are being conducted in 1991.

For more information on pheromone research, contact Richard Werner at the Pacific Northwest Research Station, Institute of Northern Forestry, 308 Tanana Drive, Fairbanks, AK 99775–5500.



Diversion trapping using baited funnel traps to remove beetles from fringe area surrounding a recent prescribed burn.

New from research

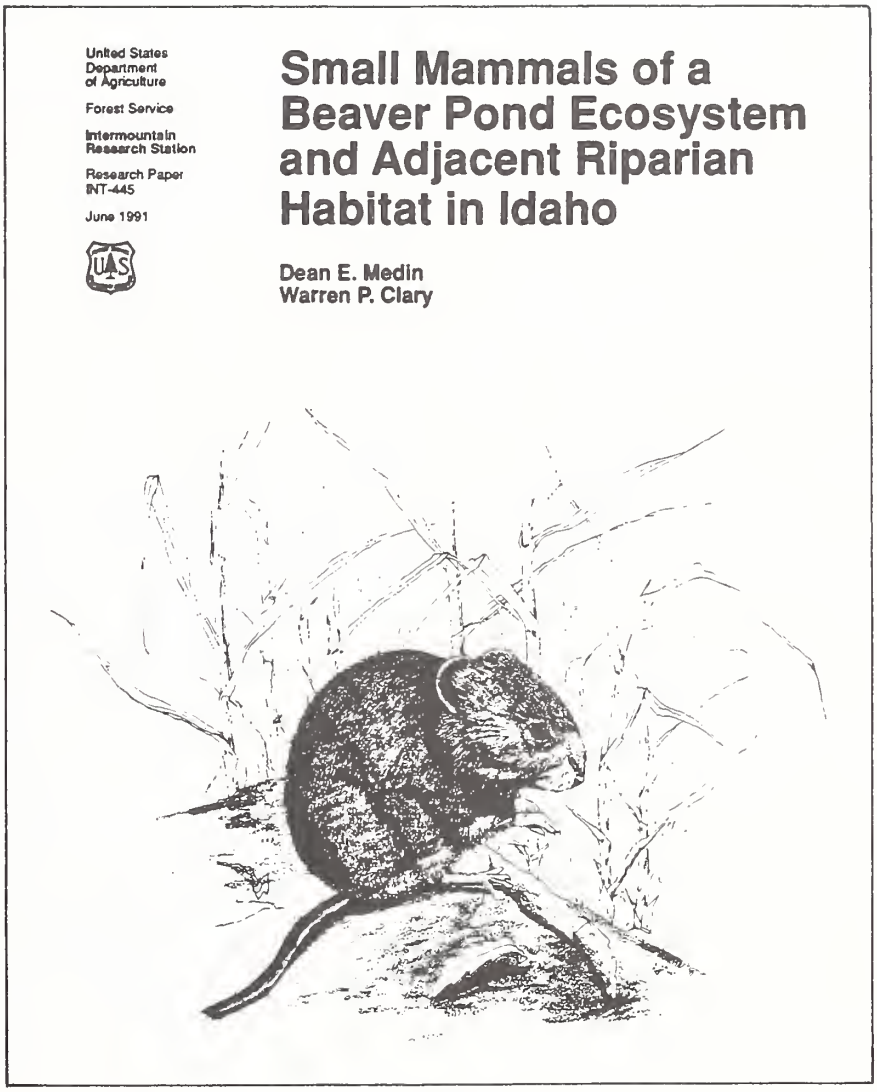
Small mammals in beaver ponds and adjacent riparian habitats

The more dense and complex mesic habitat of beaver pond ecosystems produce two to three times greater small mammal density than adjacent riparian habitat, Dean Medin and Warren Clary, Intermountain Station, learned from research on Summit Creek in east-central Idaho.

"We suggest that the dense and structurally more complex vegetation of the beaver pond ecosystem produced the food and cover resources needed to support higher relative populations of small mammals," they reported.

This research strongly demonstrates that beaver are important regulators of aquatic and terrestrial ecosystems with pervasive effects far beyond their food and space requirements.

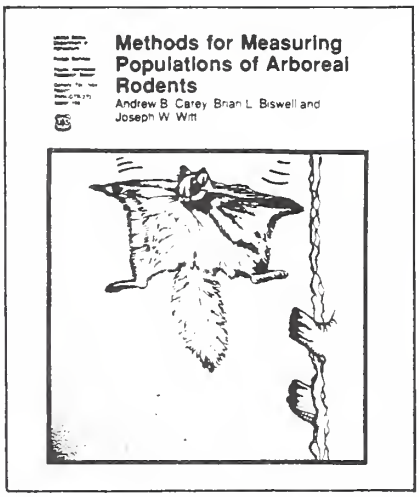
Request *Small Mammals of a Beaver Pond Ecosystem and Adjacent Riparian Habitat in Idaho,* Research Paper INT-445, available from the Intermountain Station.



Arboreal rodent populations

Three arboreal rodents are sensitive indicators of forest ecosystem function in the Pacific Northwest: the northern flying squirrel, the red tree vole, and the Douglas' squirrel. This paper discusses methods for measuring populations of these and other rodents.

Trapping with live traps is described as the most effective way to count northern flying squirrels, Townsend's chipmunks, and woodrats. Douglas' squirrels can be studied by direct observation because they are diurnal and rapidly adjust to the presence of an observer. The red tree vole is very difficult to study. No reliable method has been developed for capture except by climbing a nest tree and grabbing the voles.



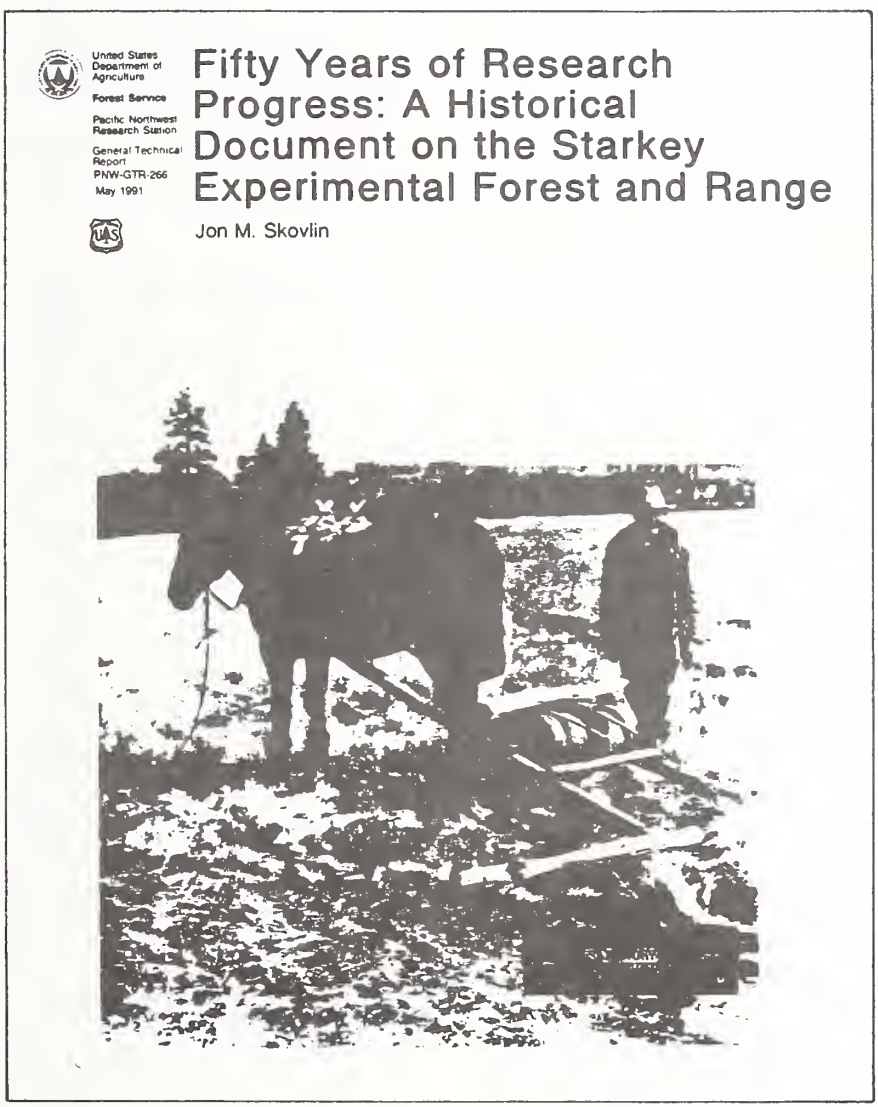
For a copy of *Methods for Measuring Populations of Arboreal Rodents*, request General Technical Report PNW-273 from the Pacific Northwest Research Station.

Advancing toward closed forest ecosystem models

In forest management, a dramatic shift is occurring in the United States toward management of forests as ecosystems rather than simply as commodity-oriented production systems. One issue of ecosystem management is that of climate change and the uncertainty about the role of forests in regulating the global atmospheric balance of CO_2, particularly in the northern hemisphere.

An important aspect in learning how ecosystems function is the ability to simulate and measure the influx and outflux of carbon and other materials in forest ecosystems. Scientists attending a recent workshop on closed forest ecosystem models concluded that a major gap exists in the modeling of the carbon cycle, particularly regarding carbon fixation by forest stands and the allocation of carbon after it has been fixed. Current models on the carbon cycle are limited, and new closed system models must be researched.

For a copy of this brief discussion on closed forest ecosystem models, request *Advancing Toward Closed Forest Ecosystem Models: Report on a Workshop*, General Technical Report RM-201 from the Rocky Mountain Station.



History of the Starkey Experimental Forest and Range

In 1940, the Starkey Experimental Forest was established. Several years later, its name was change to Starkey Experimental Forest and Range. Today it remains the only forest and range experimental area in the United States. The experimental area has been very important for the science of range management; many research methods and techniques were developed from theories tested there.

This publication traces the history of the Starkey Experimental Forest and Range. The author describes how the historical process of community development affected the evolution of forest, range, and wildlife exploitation. A list of publications from research at the experimental forest and range between 1942 and 1988 is included.

For a copy of *Fifty Years of Research Progress: A Historical Document on the Starkey Experimental Forest and Range*, request General Technical Report PNW-266 from the Pacific Northwest Research Station.

The value and harm of windbreak insects

Windbreaks are unique "mini-forest ecosystems" which contain a variety of unique insects. Even though an abundance of information on insect pests of windbreaks is available, it was never brought together until the Conference of the Entomological Society of America was held in 1988. Attendees discussed the importance and management of tree insect pests in windbreaks, and the effects of windbreaks on the survival and distribution of crop pests.

The recently published proceedings of this conference consist of 9 articles written by scientists with extensive experience in windbreak entomology. Some of the subjects include the effects of windbreaks on the overwintering of boll weevils, the damage caused by pine borers, and the general problems caused by pests in windbreaks. For a copy of *Insects of Windbreaks and Related Plantings: Distribution, Importance, and Management*, request General Technical Report RM-204 from the Rocky Mountain Station.

Juniper woodlands are valuable habitat for birds

Native woodlands constitute only a small portion of the northern Great Plains, yet they provide a specialized habitat for several species of birds. In a recent two-year study conducted in Rocky Mountain juniper woodlands, scientists found that there were consistently more birds, as well as more species of birds, in juniper stands than in neighboring grasslands. The study draws attention to the value of Rocky Mountain juniper stands—they provide food and thermal cover in the winter; migratory corridors in the fall and spring; and feeding, nesting and perching sites in the summer.

For a copy of *Rocky Mountain Juniper Woodlands: Year-Round Avian Habitat*, request Research Paper RM-296, available from the Rocky Mountain Station.

RMM software helps determine the value of recreation

A software program called Recreation Market Model (RMM) has recently been developed to give a "quick and dirty" estimate of the value of recreation. The software was designed to simulate a short-run partial equilibrium market for visits to a single recreation site. It takes into account consumer demand and the cost of operations of a certain site, as well as travel cost and access fee.

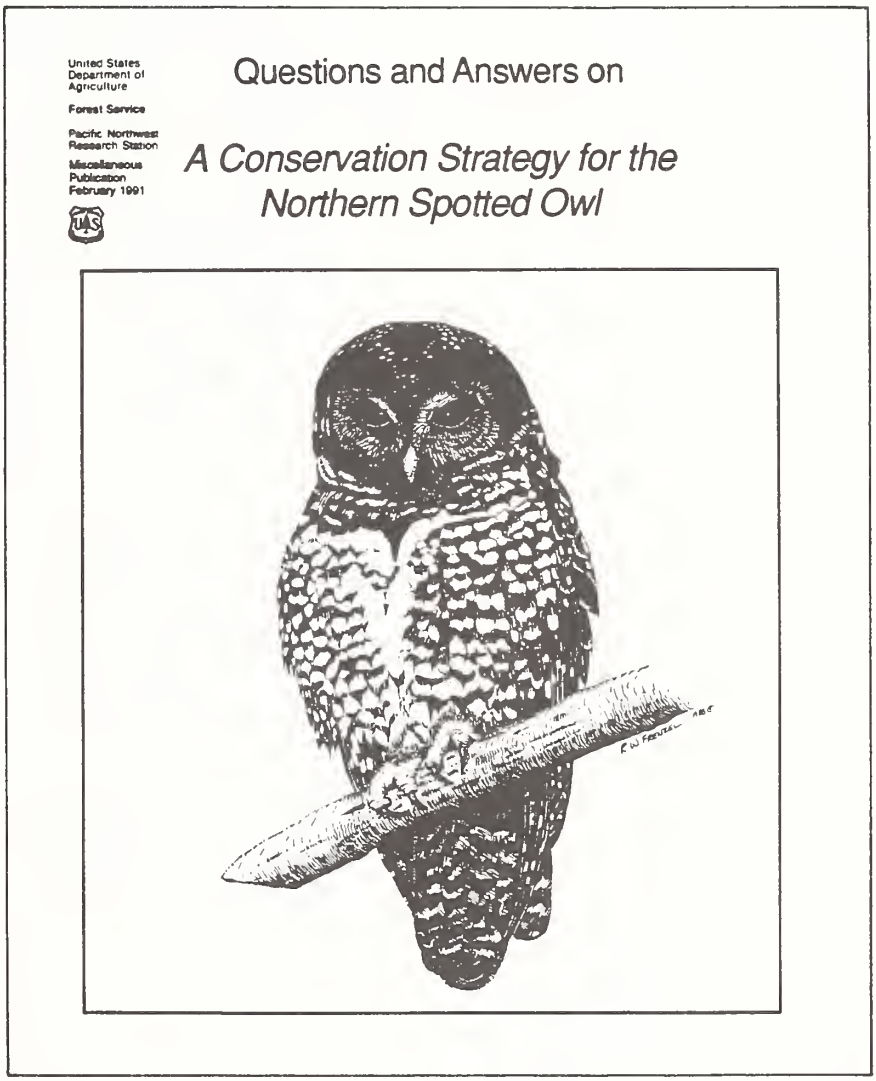
In addition, the program can estimate the supply and demand functions from data supplied by the user. It can even accept functions estimated externally by other means. If you are interested in obtaining the user's manual for the RMM software, request General Technical Report RM-202, titled *User's Guide to RMM Software: A Short-Run Partial Equilibrium Model for Economic Valuation of Wildland Resource Benefits* from the Rocky Mountain Station.

Questions and answers on the spotted owl controversy

The authors wrote this publication to clarify *A Conservation Strategy for the Northern Spotted Owl: Report of the Interagency Scientific Committee to Address the Conservation of the Northern Spotted Owl*. The questions are from a May 1990 hearing of the U.S. Senate Committee on Energy and Natural Resources.

Following are examples of questions: Do the spotted owls use only old growth throughout their home range? Do you have an accurate inventory of how many spotted owls exist today in Oregon, Washington, and northern California? And, if the northern spotted owl depends on old-growth timber for essential habitat, why are managed, second-growth forests included in the proposed habitat conservation areas?

For answers to these and 108 other questions about a conservation strategy for the spotted owl, request *Questions and Answers on A Conservation Strategy for the Northern Spotted Owl*, Miscellaneous Publication, from the PNW Research Station.

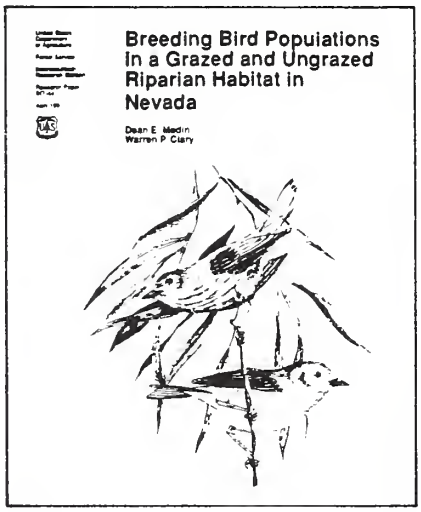


Birds in grazed and ungrazed riparian habitat

Grazing did not reduce bird productivity or diversity on the West Fork of Deer Creek in northeastern Nevada, Dean Medin and Warren Clary discovered in a study that compared breeding bird densities inside an ungrazed four hectre exclosure with the grazed riparian area outside the exclosure.

However, the Intermountain Station researchers did observe species differences between the grazed and ungrazed area. Empidonax flycatchers, warbling vireos, and MacGillivray's warblers all had higher densities in the exclosure. House wrens and song sparrows preferred the grazed area. In general, insect foraging guilds preferred the grazed communities and herbivorous/granivorous foraging guilds preferred the ungrazed.

Grazing in the study area had not seriously altered the structure between the two compared communities except in the case of seasonal grass utilization. Shrub biomass, canopy cover, and height were similar in the grazed and ungrazed areas.



This information is another piece of the puzzle needed to understand riparian ecosystems, and has added value when combined with the other knowledge acquired by the Riparian Research Work Unit based at the Boise, Idaho Forestry Sciences Laboratory.

Request *Breeding Bird Populations in a Grazed and Ungrazed Riparian Habitat in Nevada,* Research Paper INT-441, available from the Intermountain Station.

Fuel consumption by prescribed fire in logging slash

For managers concerned about sustainability and long-term productivity of forest soils after logging and slash disposal, this publication provides them with tools to help plan slash fires to leave the desired amount of duff and other organic material on the site. Equations are presented for computing moisture contents for desired levels of consumption.

The best slash fires balance between adequate site preparation and reducing the fire hazard. The authors recommend levels of fuel loading that seem best for that compromise as well as for guarding site productivity.

Request *Woody Fuel and Duff Consumption by Prescribed Fire in Northern Idaho Mixed Conifer Logging Slash,* Research Paper INT-443, available from the Intermountain Station.

To order any of the publications listed in this issue of *Forestry Research West*, use the order cards below. All cards require postage. Please remember to use your Zip Code on the return address.

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4. *Predicting Behavior and Size of Crown Fires in the Northern Rocky Mountains*, Research Paper INT-438.
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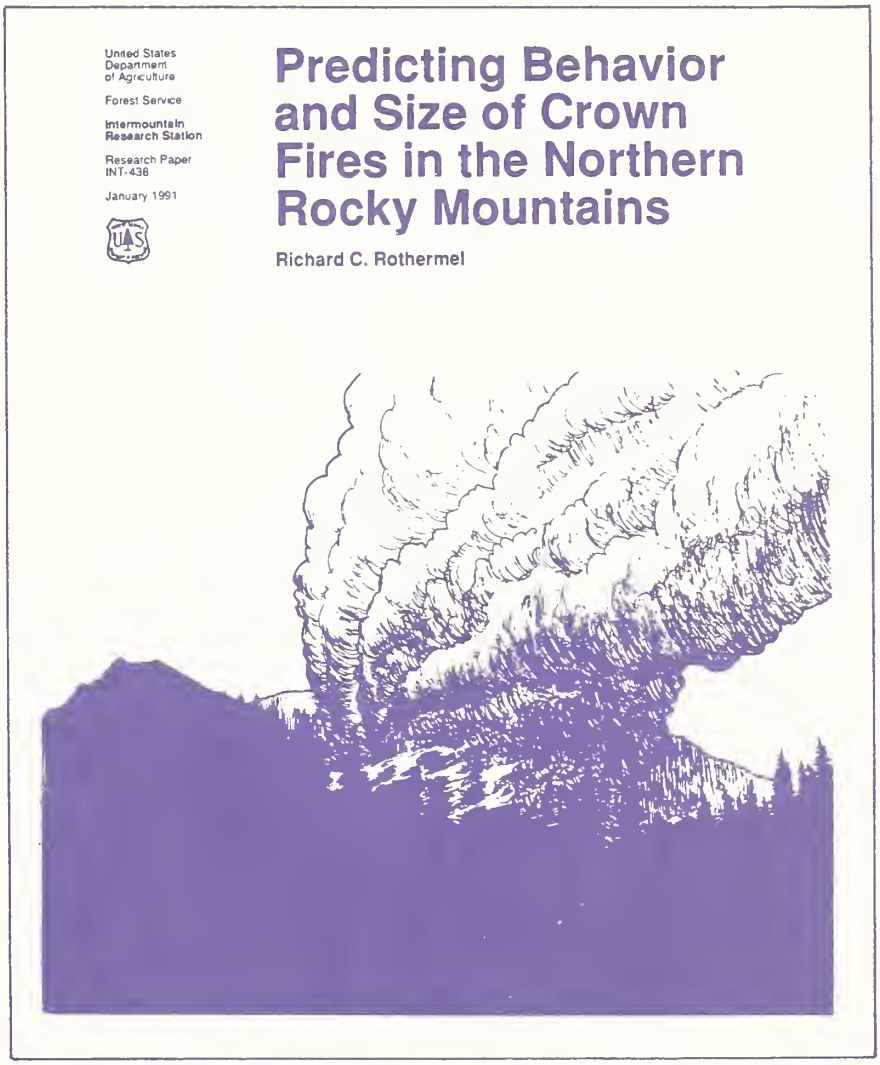
Predicting the behavior and size of crown fires

The 1988 fire season demonstrated that managers need more and better tools to predict the behavior and size of crown fires, and specialty tools to deal with extreme fire behavior like that demonstrated during that record setting year. Research Paper, INT-438, by Fire Behavior Project Leader Dick Rothermel meets part of that demand.

Rothermel wrote the paper primarily for well-trained fire behavior analysts to use in the field when they don't have computers to assess the characteristics of running crown fires. This paper provides analysts with new nomograms to help predict wind driven crown fires.

Rothermel's description of the crown fire phenomenon is interesting and informative for anyone from ground pounders to Regional Foresters who are called on to deal with extreme fire behavior. He explains the natural phenomenon that produced some of the most destructive and fatal fires.

He explains the downburst phenomenon that can occur with plume-dominated fires, such as occurred on the Shoshone Fire in Yellowstone on July 23, 1988, when trees were broken off or uprooted along a 3 1/2 mile front. Plume-dominated fires often seem deceptively safe with strong convection currents drawing the fire inward. But the convection column can collapse as it did on the Dude fire killing six firefighters in Arizona in 1990.



The paper describes indicators that warn firefighters of a soon to occur downburst.

Request *Predicting Behavior and Size of Crown Fires in the Northern Rocky Mountains,* Research Paper INT-438, available from the Intermountain Station.

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